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Test of a De Laval Turbo-Pump

Mechanical Engineering

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TEST OF A DE LAVAL TURBO-PUMP

BY

Alfred Rittscher Bench
Louis Paul Robert

THESIS FOR THE DEGREE OF BACHELOR OF SCIENCE
IN MECHANICAL ENGINEERING

IN THE
COLLEGE OF ENGINEERING
OF THE
UNIVERSITY OF ILLINOIS
PRESENTED JUNE, 1906

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June 1, 1906

THIS IS TO CERTIFY THAT THE THESIS PREPARED UNDER MY SUPERVISION BY

ALFRED RITTSCHER BENCH and LOUIS PAUL ROBERT

ENTITLED TEST OF A DE LAVAL TURBO-PUMP

IS APPROVED BY ME AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE DEGREE

OF Bachelor of Science in Mechanical Engineering

L. P. Breckenridge.

HEAD OF DEPARTMENT OF Mechanical Engineering

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TEST OF A DE LAVAL TURBO PUMP.

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TEST OF A DE LAVAL TURBO PUMP.

I Preliminary Remarks.

The following is a report of tests made on a De Laval Turbo Pump at the Mechanical Engineering Labaratory of the University of Illinois, from April 10 to April 24, 1906. The parties in charge of the tests were A. R. Bench and L. P. Robert, under the supervision of Professor D. T. Randall.

II Object.

The object of the tests was to determine the performance of the pump, with the turbine running both condensing and non-condensing, in the following particulars.

(a) To determine the economy of the steam driven turbo pump by determining the number of pounds of commercially dry steam consumed per water horse power hour.

(b) To measure the capacity of the pump over a range of delivery heads varying from 50 pounds to 217 pounds per square inch pressure.

(c) To find out if it would be an economical proposition to install a De Laval steam turbo pump in the pump room of the University heating plant to furnish feed water to the boilers.

(d) To verify the claims of the manufacturers that the pump was capable of delivering 140 gallons of water per minute against 500 feet head.

III Description of Apparatus.

a. Pump.

The pump tested was a two stage centrifugal pump Number 3640, Type I. X. P., manufactured by the De Laval Steam Turbine Company of Trenton, New Jersey. It was designed for a delivery of 140 gallons of water per minute against a head of 500 feet which corresponds to a delivery of .312 cubic feet of water per second against a pressure of 217 pounds per square inch.

The low pressure pump wheel was driven at a speed of 2200 revolutions per minute by direct gearing to the shaft of the turbine wheel. The high pressure pump wheel was driven at a speed of 22000 revolutions by direct connection to the shaft of the turbine wheel.

The dimensions of the pump are as follows:

	Low Pressure.	High Pressure.
Diameter of Suction	4 inches	4 inches
" " Discharge	4 "	3 "
" " Pump Wheel	7 "	2 "
Number of Vanes	4	6
Width of Vanes	$\frac{1}{2}$ inches	$\frac{5}{16}$ inches

The pump was so arranged that it lifted the water about six feet from a large concrete tank under the floor

line of the Laboratory. The dimensions of the tank are 12' x 6' x 6' and it contained approximately 2300. gallons of water.

b. Measuring Box.

The water from the turbine was delivered to a jet measuring box, where it was measured and discharged back into the tank. This jet measuring box is as shown in figure 1, page 38. The glass tube T has an internal diameter of .5 inch and is provided with a brass tip F. This tip is about 1.5 inches long and conical in shape. It has a bore of .12 inch, this being made small in order to reduce the fluctuation of the water column in the tube. It is adjusted concentrically and even with the top face of the discharge pipe in the box. The clamps as shown in the figure, provide for a vertical adjustment of the tube, enabling it to be easily adjusted in the proper position. A wooden rod was placed in the clamps along side of the tube. This rod was graduated to tenths and hundredths of a foot.

The measuring box was calibrated in the Hydraulic Laboratory of the University of Illinois by C. V. Seastone "95. The results of this calibration were published in the Technograph, Volume XIV, page 98. By duplicating the apparatus used by Mr. Seastone, it was made possible to use his results in the determination of the water discharged. A curve showing coefficients obtained by Mr. Seastone is shown on page 29 .

c. Condenser.

The condenser used was a Wheeler surface con-

denser. The cooling water used to condense the exhaust steam was piped from a stream a short distance away and discharged back into it. The condensed steam was run into a tank set on a platform scale and weighed.

d. Steam Gauges.

The steam pressure gauges were placed, one just above the governor throttle valve of the turbine, and one just below it, so that the differences in pressure between the two could be obtained. The gauge just below the throttle valve indicated the steam pressure at entrance to the turbine nozzles.

e. Water Gauges.

A pressure gage was placed in the delivery pipe of the low pressure pump in order to find out at what pressure the water was delivered to the high pressure pump.

Another gauge was placed on the delivery pipe of the high pressure pump just under the throttling valve.

All gauges were calibrated by the Crosby oil gauge tester in the instrument room of the Mechanical Engineering Laboratory.

f. Speed Indicator.

The method of taking speeds of the turbine was by the use of a tachometer on the low pressure pump shaft. If these results are multiplied by ten, the speeds of the high pressure pump and of the turbine are obtained. The tachometer was not calibrated and the results can not be proved to be strictly accurate.

IV Manner of Conducting Test.

a. Method of Starting.

The pumps, as a rule, had to be primed before starting owing to a defect in the foot valve in the intake pipe.

The turbine was brought slowly up to governor speed and the total head of water was increased to the working pressure by means of the throttle valve on the delivery pipe from the high pressure wheel. The pump was allowed to run from ten to fifteen minutes before readings were taken in order to get everything under normal conditions.

b. Readings and Duration of Tests.

Readings were taken at ten minute intervals for a period of two hours for each head while running both condensing and non-condensing. The readings taken were; (1) steam pressure above the throttle valve, given as"Steam I" in the tables; (2) the steam pressure below the throttle valve, given as "Steam II" in the tables; (3) the water pressure above the high pressure pump; (4) the vacuum, in the tests running condensing; (5) the R. P. M.; and (6) the height of the water in the tube.

c. Method of Measuring Steam.

The steam was condensed in all tests and weighed on platform scales.

V Methods of Calculation.

a. Method of finding the discharge.

The discharge in cubic feet per second was found from the formula $Q_1 = ca\sqrt{2gh}$ in which "Q_1" is the discharge in cubic feet per second, "c" is a coefficient depending on the height of the water column and the size of the pipe in the measuring box, "a" is the area of the pipe in the measuring box in square feet, "g" is the acceleration due to gravity, 32.16, "h" is the height of the water in the tube. The coefficient "c" was obtained from the curves plotted by Mr. Seastone in his calibration of the measuring box. The discharge in gallons per minute, "Q_2", was found from Q_1 by multiplying by 7.48, the number of gallons in one cubic foot, and by 60, thus getting gallons per minute. Taking the reading for 3:00 o'clock in test number 1 for an illustration, the coefficient for h = 1.58 and a 3" pipe is .8232, a = .0525 sq. ft.

$$Q_1 = .8232 \times .0525 \times \sqrt{64.32 \times 1.58} = .435 \text{ cu. ft. per sec.}$$

$$Q_2 = .435 \times 7.48 \times 60 = 195.5 \text{ gal. per minute.}$$

b. Method of finding Water Horse Power.

The horse power is obtained from Q_1, by the formula $H.P. = \frac{Q_1 \times 62.5 \times \text{ft. lift}}{550}$. The feet lift was taken as the reading of the gauge above the high pressure pump reduced to feet of water, plus the distance from the gauge pipe to the surface of the water in the pit.

To illustrate,

50 lbs per sq. in. x 2.304 = 115.2 ft.
distance from water to gauge = 6.3 "
Total lift = 121.5 "

$$\text{H.P.} = \frac{.435 \times 62.5 \times 121.5}{550} = 6.02 \text{ H. P.}$$

c. Method of Finding Steam Consumption.

The steam consumption per water horse power hour was found by dividing the total steam consumption for the two hour run by two and by the average horse power for the test. That is,

$$\text{Steam consumption per water horse power hour} = \frac{\text{total steam consumption}}{2 \times \text{average W. H. P.}}$$

For example the average water horse power developed in the first test was 6.04. The total steam consumption was 2025 pounds.

$$\text{Steam consumption per W. H. P. hr.} = \frac{2025}{2 \times 6.04} = 167.6 \text{ lbs}$$

VI Description of Tables and Curves.

a. Tables.

The tables giving the data for each test contain the data taken at each reading, namely, the steam pressure above (Steam I) and below (Steam II) the governing throttle valve, the water pressure in the pipe above the high pressure pump, the vacuum in inches for the tests running condensing, the R. P. M. of the low pressure pump and the heighth of the water in the tube of the measuring box. The tables also give the calculated results for each reading and the coefficient of discharge used in each case. The calculated results are the discharge or amount of water pumped in cubic feet per second also in gallons per minute, and the water horse power developed. Below each table is

found the steam consumption per water horse power hour using the average water horse power developed in the two hour run. This steam consumption is of commercially dry steam. From calometer tests the steam was found to contain on the average, about 1.5 per cent of moisture.

On page 12 is a table giving the average results of each test, that is the total lift in feet, the gallons per minute pumped, the water horse power developed and the steam consumption per water horse power hour. This table shows a comparison between the results running non-condensing and those running condensing.

b. Curves.

The curves on page 30 shows the relation between the total lift in feet and the number of gallons delivered by the pump per minute with the turbine running condensing. Curve number 2 shows the same relation with the turbine running non-condensing. Curves number 3 and 4 show the relation between the steam consumption per water horse power hour and the water horse power developed. On pages 34 and 35 are curves number 5 and 6 showing the relation between the total lift and the water horse power developed with the turbine running condensing, and non-condensing respectively. Curves number 7 and 8 show the relation between the duty in foot pounds of work per 1000 pounds of steam and the gallons per minute pumped.

VII Conclusions.

a. Economy.

The most economical steam consumption running non-condensing was 73.2 pounds per water horse power per hour, and running condensing was 63.9 pounds per water horse power per hour. When the fact that the average horse power for the former was 17.68 and for the latter 17.45, is considered, the rate is good. The turbine was not running under ideal conditions but rather under ordinary conditions. For an engine of that power under ordinary conditions the rate was not any higher than other engines. Running condensing the lowest steam rate was reached at the maximum horse power. In the case of the tests running non-condensing, the lowest rate was reached at a little under the maximum horse power. As would be expected, the water rate increased with a decrease in the horse power developed.

b. Boiler Feed Pump.

The average steam pressure in the University plant is 150 pounds per square inch. Taking the values for a head of 352 feet or a little more than 150 pressure, the steam consumption, running non-condensing as a boiler feed pump would run, is 75.1 pounds per water horse power hour. For boiler feed pump service this is satisfactory. The discharge was 189.9 gallons per minute or 95000 pounds per hour. Considering a boiler horse power to take 34.5 pounds of water per hour at and from

212 degrees, the 2000 horse power of boilers in the University plant would take a maximum of 69000 pounds of water per hour. From these figures, it is seen that the pump would easily supply enough water. If used as a boiler feed pump, it should give very satisfactory results.

c. Capacity.

As is seen from the table page 12 , the pump came very close to delivering the rated amount of 140 gallons per minute against a head of 500 feet. It did this under poor conditions. The throttle valve used to obtain the desired pressure, was very near the discharge of the high pressure pump and the shocks caused by this would tend to decrease the discharge.

d. General.

On the whole the tests showed the pump to be very satisfactory. The steam consumption at or near full load was fairly good. It should be remembered that this is based on water horse power and that all the losses in the pump and turbine are contained in it. If figured on the horse power delivered by the turbine, the steam consumption would probably not be over .75 of the values given. The pump came up to the rated capacity probably as near as could be expected under the conditions.

TABLE OF RESULTS

TOTAL LIFT	DISCHARGE Gals. per Min.	WATER HORSE POWER	STEAM CONSUMPTION per W.H.P. Hr.
CONDENSING			
121.2	203.8	6.26	127.0
178.8	183.6	8.31	102.1
236.4	184.9	11.06	82.0
294.0	158.7	11.82	81.7
351.6	157.2	13.90	76.1
409.2	158.2	16.39	67.8
466.8	147.5	17.45	63.9
506.0	132.6	17.00	64.9
NON CONDENSING			
121.5	196.5	6.04	167.6
179.1	199.4	8.90	124.0
236.1	196.6	11.77	99.3
293.8	192.6	14.40	81.5
352.0	189.8	16.92	75.1
409.2	170.1	17.68	73.2
466.8	155.6	18.47	73.8
506.0	136.0	17.44	75.3

TEST NO I

TIME	PRESSURES			R.P.M.	h	COEF.	Q_1 $\frac{cu.ft}{sec.}$	Q_2 $\frac{Gall}{min.}$	H.P.
	STEAM I	STEAM II	WATER						
2:30	120		50	2160	1.66	.8235	.446	199.8	6.15
:40	118		"	2160	1.60	.8230	.438	197.0	6.06
:50	117		"	2150	1.54	.8230	.428	192.5	5.92
3:00	120		"	2160	1.58	.8232	.435	195.5	6.02
:10	118		"	2160	1.53	.8230	.428	192.5	5.92
:20	120		"	2160	1.54	.8230	.428	192.5	5.92
:30	120		"	2180	1.70	.8240	.453	203.2	6.25
:40	120		"	2160	1.66	.8235	.447	201.0	6.17
:50	117		"	2160	1.65	.8234	.447	201.0	6.17
4:00	117		"	2160	1.58	.8232	.435	195.5	6.02
:10	116		"	2100	1.55	.8230	.428	192.5	5.92
:20	118		"	2160	1.58	.8232	.435	195.5	6.02
:30	87		"	2160	1.58	.8232	.435	1.95.5	6.02
AV.	116		50	2156				196.5	6.04

TOTAL STEAM CONSUMPTION = 2025 LB'S

STEAM PER WATER H.P. HOUR = 167.6 LB'S.

TOTAL LIFT = 121.5 FT.

TEST No 2.

TIME	PRESSURES			R.P.M.	h	COEF.	$Q_1 \frac{cu.ft}{sec.}$	$Q_2 \frac{Gall}{min.}$	H.P.
	STEAM I	STEAM II	WATER						
2:20	98	89	75	2110	1.79	.824	.450	202.5	9.20
:30	90	82	"	2110	1.70	.823	.438	197.0	8.95
:40	95	85	"	2160	1.76	.823	.446	200.5	9.10
:50	95	87	"	2080	1.62	.8225	.428	192.5	8.75
3:00	95	82	"	2160	1.75	.823	.445	200.0	9.08
:10	97	81	"	2140	1.74	.823	.443	199.0	9.04
:20	94	79	"	2180	1.78	.824	.448	201.5	9.15
:30	94	74	"	2100	1.76	.823	.446	200.5	9.10
:40	92	78	"	2160	1.75	.823	.445	200.0	9.08
:50	88	74	"	2160	1.74	.823	.443	199.0	9.04
4:00	101	82	"	2160	1.76	.823	.446	200.5	9.10
:10	91	79	"	2160	1.73	.823	.443	199.0	9.04
:20	94	79	"	2160	1.77	.824	.446	200.5	9.10
AVER.	94.2	80.9	75	2141				199.4	9.05

TOTAL STEAM CONSUMPTION = 2207 LB'S

STEAM PER WATER H. P. HOUR = 121.9 LB'S.

TOTAL LIFT = 179.1 FT

TEST No3.

TIME	PRESSURES			R.P.M.	h	COEF.	Q_1 $\frac{cu\ ft}{sec}$	Q_2 $\frac{gall}{min}$	H. P.
	STEAM I	STEAM II	WATER						
1:20	87	79	100	2080	1.62	.824	.442	198.2	11.85
:30	74	65	"	2040	1.55	.823	.431	193.0	11.55
:40	130	98	"	2200	1.79	.825	.464	206.3	12.46
:50	130	100	"	2200	1.77	.825	.462	205.4	12.41
2:00	118	75	"	2180	1.60	.823	.438	196.8	11.76
:10	106	78	"	2160	1.56	.823	.432	193.9	11.59
:20	108	78	"	2180	1.55	.823	.431	193.0	11.55
:30	117	85	"	2200	1.55	.823	.431	193.0	11.55
:40	123	88	"	2200	1.54	.823	.430	192.9	11.55
:50	116	93	"	2180	1.50	.8225	.423	189.6	11.34
3:00	126	111	"	2180	1.62	.824	.442	198.2	11.85
:10	125	105	"	2160	1.62	.824	.442	198.2	11.85
:20	115	100	"	2160	1.60	.823	.438	196.8	11.76
AVER.	113.5	88.8	100	2163.				196.6	11.77

TOTAL STEAM CONSUMPTION = 2335 LB'S

STEAM PER WATER H. P. HOUR = 99.3 LB'S

TOTAL LIFT = 236.1 FT

TEST No 4

TIME	PRESSURES			R.P.M.	h.	COEF.	Q_1 $\frac{cu\ ft}{sec}$	Q_2 $\frac{Gall}{min}$	H. P.
	STEAM I	STEAM II	WATER						
1:10	125	89	125	2200	1.63	.824	.443	199.0	14.80
:20	117	104	"	2180	1.60	.823	.438	196.8	14.64
:30	111	102	"	2160	1.53	.8225	.428	192.5	14.32
:40	121	104	"	2180	1.60	.823	.438	196.8	14.64
:50	130	117	"	2180	1.59	.823	.436	195.4	14.52
2:00	130	120	"	2160	1.53	.8225	.428	192.5	14.32
:10	127	118	"	2160	1.55	.823	.431	193.0	14.36
:20	122	114	"	2140	1.49	.822	.422	189.0	14.05
:30	127	120	"	2160	1.47	.822	.419	188.2	14.00
:40	125	118	"	2140	1.49	.822	.422	189.0	14.05
:50	129	120	"	2160	1.51	.8225	.425	190.7	14.67
3:00	130	120	"	2160	1.51	.8225	.425	190.7	14.67
:10	129	119	"	2160	1.50	.8225	.423	189.6	14.10
AVER.	124	112.7	125	2165				192.6	14.40

TOTAL STEAM CONSUMPTION = 2349 LB'S

STEAM PER WATER H. P. HOUR = 81.5 LB'S

TOTAL LIFT = 293.75 FT.

TEST No5

TIME	PRESSURES			R.P.M.	h	COEF.	Q_1 $\frac{cu.ft}{sec}$	Q_2 $\frac{Gall}{min}$	H. P.
	STEAM I	STEAM II	WATER						
8:50	89	79	150	2080	1.39	.822	.408	183.0	16.32
9:00	107	90	"	2160	1.53	.823	.428	192.5	17.17
:10	112	98	"	2160	1.55	.823	.431	193.0	17.22
:20	102	94	"	2100	1.47	8225	.419	188.5	16.75
:30	100	88	"	2140	1.49	.8225	.422	189.0	16.83
:40	108	98	"	2140	1.50	.8225	.423	189.8	16.90
:50	118	105	"	2160	1.54	.823	.430	193.0	17.22
10:00	118	108	"	2160	1.50	.8225	.423	189.8	16.90
:10	120	110	"	2160	1.51	8226	.425	191.0	17.00
:20	125	120	"	2100	1.46	.8225	.418	187.5	16.70
:30	108	100	"	2100	1.47	.8225	.419	188.5	16.75
:40	115	100	"	2180	1.47	.8225	.419	188.5	16.75
:50	125	110	"	2180	1.58	.8234	.435	195.5	17.41
AVER.	111.3	100.	150	2140				189.8	16.92

TOTAL STEAM CONSUMPTION = 2542 LB'S

STEAM PER WATER H.P. HOUR = 75.1 LB'S

TOTAL LIFT = 352 FT.

TEST No 6

TIME	PRESSURES			R.P.M.	h	COEF.	$Q_1 \frac{cu\,ft}{sec}$	$Q_2 \frac{Gall.}{min}$	H.P.
	STEAM I	STEAM II	WATER						
1:00	116	107	175	2100	1.09	.817	.359	161.2	16.73
:10	107	92	"	2160	1.21	.820	.380	170.8	17.70
:20	139	122	"	2200	1.30	.821	.394	177.0	18.38
:30	106	90	"	2160	1.19	.819	.376	169.0	17.50
:40	114	90	"	2180	1.14	.818	.368	165.2	17.15
:50	114	102	"	2160	1.13	.818	.366	164.0	17.02
2:00	115	102	"	2160	1.23	.820	.383	172.0	17.85
:10	118	106	"	2160	1.20	.819	.377	169.2	17.55
:20	120	108	"	2140	1.23	.820	.383	172.0	17.85
:30	124	111	"	2160	1.24	.821	.386	173.1	18.08
:40	118	105	"	2160	1.24	.821	.386	173.1	18.08
:50	109	97	"	2140	1.23	.820	.383	172.0	17.85
3:00	112	96	"	2160	1.24	.821	.386	173.1	18.08
AVER.	116.3	102	175	2157				170.1	17.68

TOTAL STEAM CONSUMPTION = 2587 LB'S

STEAM PER WATER H.P. HOUR = 73.2 LB'S

TOTAL LIFT = 409.2 FT

TEST No7

TIME	PRESSURES			R.P.M.	h	COEF.	Q_1 $\frac{cu\,ft}{sec}$	Q_2 $\frac{Gall}{min}$	H.P.
	STEAM I	STEAM II	WATER						
3:00	121	108	200	2180	1.07	.818	.356	159.3	18.87
:10	122	111	"	2160	1.01	.8172	.3455	154.4	18.25
:20	117	105	"	2160	1.06	.818	.355	159.0	18.84
:30	115	104	"	2160	1.04	.8175	.351	157.3	18.56
:40	113	100	"	2180	1.05	.8176	.352	158.0	18.67
:50	100	90	"	2140	1.00	.817	.344	150.0	17.72
4:00	98	88	"	2100	.93	.816	.331	148.7	17.55
:10	99	89	"	2100	.94	.8164	.333	149.4	17.64
:20	116	97	"	2200	1.11	.8181	.363	164.0	19.26
:30	114	103	"	2140	1.03	.8175	.349	156.6	18.50
:40	105	94	"	2100	.92	.816	.329	147.5	17.45
:50	111	97	"	2160	1.01	.8172	.3445	154.5	18.25
5:00	135	114	"	2200	1.14	.8184	.368	165.2	19.51
AVER.	112.8	100	200.	2152				155.6	18.47

TOTAL STEAM CONSUMPTION = 2727 LB'S

STEAM PER WATER H.P. HOUR = 73.8 LB'S

TOTAL LIFT = 466.8 FT.

TEST No 8

TIME	PRESSURES			R.P.M.	h.	COEF.	$Q_1\ \frac{\text{cu ft}}{\text{sec}}$	$Q_2\ \frac{\text{Gall}}{\text{min}}$	H.P.
	STEAM I	STEAM II	WATER						
12:55	118	102	217	2180	.87	.814	.312	140.0	17.95
1:05	122	108	"	2160	.86	.814	.310	139.0	17.81
:15	129	111	"	2180	.81	.813	.301	135.0	17.30
:25	128	115	"	2180	.84	.814	.306	137.0	17.58
:35	125	115	"	2180	.82	.813	.302	135.5	17.35
:45	128	115	"	2180	.84	.814	.306	137.0	17.58
:55	120	108	"	2140	.82	.813	.302	135.5	17.35
2:05	124	110	"	2160	.82	.813	.302	135.5	17.35
:15	125	110	"	2180	.87	.814	.312	140.0	17.95
:25	125	115	"	2160	.77	.812	.292	131.0	16.80
:35	132	111	"	2160	.78	.812	.294	132.0	16.90
:45	123	100	"	2160	.80	.813	.299	134.0	17.20
:55	128	102	"	2160	.84	.814	.306	137.0	17.58
AVER.	125	109.4	217.	2169.2				136.0	17.44

TOTAL STEAM CONSUMPTION = 2623 LB'S

STEAM PER WATER H.P. HOUR = 75.25 LB'S

TOTAL LIFT = 506 FT.

TEST No. 9.

TIME	PRESSURES			VACUUM	R.P.M.	h	COEF.	$Q_1 \frac{cu.ft}{sec.}$	$Q_2 \frac{gall.}{min}$	H. P.
	STEAM I	STEAM II	WATER							
1:10	122	100	50	20.2	2200	1.78	825	.463	207.5	6.375
:20	116	95	"	20.2	2200	1.73	.825	.457	205.5	6.300
:30	112	94	"	19.8	2200	1.69	.824	.451	202.5	6.220
:40	115	90	"	19.8	2200	1.75	.825	.460	206.5	6.340
:50	114	89	"	19.1	2200	1.74	.825	.458	205.8	6.330
2:00	136	90	"	19.7	2210	1.75	.825	.460	206.5	6.340
:10	135	103	"	18.5	2200	1.70	.824	.452	203.0	6.225
:20	136	102	"	19.7	2200	1.70	.824	.452	203.0	6.225
:30	137	113	"	19.4	2200	1.69	.824	.451	202.5	6.220
:40	138	116	"	19.4	2200	1.68	.824	.449	201.5	6.190
:50	127	110	"	19.1	2200	1.66	.823	.446	200.0	6.140
3:00	125	96	"	19.9	2200	1.70	.824	.452	203.0	6.225
:10	130	96	"	19.9	2200	1.69	.824	.451	202.5	6.220
AVER.	126.5	99.5	50	19.6	2200.8				203.8	6.260

TOTAL STEAM CONSUMPTION = 1592 LB'S

STEAM PER WATER H.P. HOUR = 127 LB'S

TOTAL LIFT = 121.2 FT.

TEST No. 10.

TIME	PRESSURES			VACUUM	R. P. M.	h	COEF.	Q_1 $\frac{cu.ft.}{sec.}$	Q_2 $\frac{gall}{min}$	H. P.
	STEAM I	STEAM II	WATER							
1:10	135	116	75	20.0	2180	1.57	.8230	.433	194.6	8.81
:20	128	107	"	19.9	2200	1.48	.8225	.421	189.0	8.55
:30	136	106	"	19.8	2200	1.50	.8226	.424	190.5	8.62
:40	138	112	"	19.5	2200	1.48	.8225	.421	189.0	8.55
:50	122	112	"	16.5	2100	1.40	.8220	.409	183.9	8.32
2:00	134	115	"	19.0	2180	1.40	.8220	.409	183.9	8.32
:10	126	111	"	18.9	2180	1.36	.8216	.403	181.1	8.19
:20	120	95	"	19.0	2200	1.34	.8214	.401	180.3	8.16
:30	117	94	"	19.9	2200	1.35	8215	.402	180.7	8.17
:40	113	75	"	20.0	2200	1.34	.8214	.401	180.3	8.16
:50	120	97	"	20.0	2200	1.33	.8213	.399	178.9	8.10
3:00	120	100	"	20.0	2180	1.32	.8212	.397	178.2	8.06
:10	118	98	"	20.0	2160	1.30	.8210	.394	176.7	8.00
AVER.	125.2	102.9	75	19.42	2183				183.6	8.31

TOTAL STEAM CONSUMPTION = 1694 LB'S

STEAM PER WATER H.P. HOUR = 102.1 LB'S

TOTAL LIFT = 178.8 FT.

TEST No. 11.

TIME.	PRESSURES			VACUUM	R. P. M.	h	COEF.	$Q_1 \frac{cu.ft.}{sec.}$	$Q_2 \frac{gall}{min.}$	H. P.
	STEAM I	STEAM II	WATER							
1:10	131	109	100	19.4	2200	1.44	.822	.415	186.5	11.15
:20	122	94	"	19.7	2200	1.47	.823	.420	188.2	11.25
:30	127	102	"	19.7	2200	1.47	.823	.420	188.2	11.25
:40	129	102	"	19.7	2200	1.45	.822	.416	187.0	11.18
:50	124	100	"	19.7	2200	1.44	.822	.415	186.5	11.15
2:00	121	100	"	19.6	2200	1.42	.822	.412	184.8	11.05
:10	126	106	"	15.5	2180	1.40	.821	.408	183.5	10.98
:20	125	105	"	16.8	2180	1.42	.822	.412	184.8	11.05
:30	121	101	"	17.0	2200	1.41	.821	.410	184.0	11.00
:40	132	112	"	17.0	2180	1.40	.821	.408	183.5	10.98
:50	136	116	"	16.0	2180	1.41	.821	.410	184.0	11.00
3:00	133	115	"	16.7	2140	1.38	.821	.405	182.0	10.88
:10	122	113	"	16.0	2160	1.36	.821	.403	181.0	10.82
AVER.	126.8	113.5	100	17.8	2186				184.9	11.06

TOTAL STEAM CONSUMPTION = 1814 LB'S

STEAM PER WATER H.P. HOUR = 82 LB'S

TOTAL LIFT = 236.4 FT.

TEST NO. 12.

TIME	PRESSURES			VACUUM	R.P.M.	h	COEF.	$Q_1 \frac{cu.ft.}{sec}$	$Q_2 \frac{gall}{min}$	H.P.
	STEAM I	STEAM II	WATER							
9:45	130	110	125	16.8	2160	1.37	.822	.404	181.4	13.50
:55	129	104	"	15.1	2200	1.38	.822	.406	182.3	13.58
10:05	127	105	"	17.0	2200	1.36	.822	.403	181.0	13.48
:15	127	110	"	17.0	2180	1.32	.822	.397	178.2	13.27
:25	132	112	"	17.0	2200	1.16	.819	.370	166.1	12.36
:35	138	110	"	17.0	2200	1.02	.818	.347	156.0	11.61
:45	126	106	"	17.0	2160	.98	.817	.340	152.5	11.37
:55	121	95	"	16.4	2160	.88	.815	.321	147.2	10.96
11:05	125	92	"	18.0	2200	.86	.814	.317	142.4	10.60
:15	118	90	"	18.0	2180	.87	.815	.319	143.2	10.65
:25	116	89	"	18.0	2180	.88	.815	.321	147.2	10.96
:35	119	97	"	18.0	2160	.86	.814	.317	142.4	10.60
:45	124	99	"	18.1	2180	.87	.815	.319	143.2	10.65
AVER.	125.5	101.5	125	17.2	2182				158.7	11.82

TOTAL STEAM CONSUMPTION = 1931 LB'S

STEAM PER WATER H.P. HOUR = 81.7 LB'S

TOTAL LIFT = 294 FT.

TEST No. 13.

TIME	PRESSURES STEAM I	PRESSURES STEAM II	PRESSURES WATER	VACUUM	R.P.M.	h	COEF.	Q_1 $\frac{cu.ft}{sec.}$	Q_2 $\frac{gall}{min.}$	H.P.
12:45	115	94	150	17.5	2160	1.09	.818	.360	162.0	14.40
:55	104	86	"	17.7	2100	1.01	.817	.345	155.0	13.80
1:05	105	87	"	17.7	2100	.96	.816	.337	152.5	13.56
:15	119	94	"	18.0	2160	1.07	.818	.356	161.5	14.25
:25	118	92	"	18.0	2140	1.04	.817	.350	157.5	14.00
:35	116	93	"	18.0	2180	1.06	.818	.350	157.5	14.00
:45	120	95	"	18.0	2180	1.06	.818	.350	157.5	14.00
:55	112	92	"	18.0	2140	1.02	.817	.347	156.0	13.90
2:05	103	85	"	17.2	2060	.96	.816	.337	152.5	13.56
:15	104	86	"	17.0	2060	.95	.816	.335	150.5	13.40
:25	110	92	"	17.1	2120	.98	.816	.340	153.0	13.60
:35	113	92	"	17.2	2160	1.03	.817	.349	156.5	13.95
:45	116	104	"	17.2	2160	1.05	.817	.352	158.0	14.08
AVER.	112	91.7	150	17.6	2132				157.2	13.90

TOTAL STEAM CONSUMPTION = 2122 LB'S

STEAM PER WATER H.P. HOUR = 76.1 LB'S

TOTAL LIFT = 351.6 FT.

TEST NO. 14

TIME	PRESSURES			VACUUM	R.P.M.	h	COEF.	$Q_1 \frac{cu.ft.}{sec.}$	$Q_2 \frac{gall}{min}$	H. P.
	STEAM I	STEAM II	WATER							
1:35	130	100	175	20.0	2200	1.06	.818	.354	158.8	16.45
:45	128	100	"	19.0	2200	1.07	.818	.356	159.8	16.57
:55	132	102	"	18.7	2200	1.06	.818	.354	158.8	16.45
2:05	128	88	"	18.7	2200	1.05	.818	.352	158.0	16.38
:15	120	80	"	18.5	2140	1.03	.818	.349	156.6	16.23
:25	115	65	"	18.4	2140	1.01	.818	.346	155.2	16.10
:35	134	70	"	18.4	2200	1.06	.818	.354	158.8	16.45
:45	135	60	"	18.4	2200	1.08	.818	.357	160.1	16.60
:55	135	60	"	18.4	2180	1.06	.818	.354	158.8	16.45
3:05	135	60	"	18.5	2180	1.02	.818	.347	155.7	16.14
:15	140	60	"	18.4	2200	1.05	.818	.352	158.0	16.33
:25	130	45	"	18.4	2200	1.05	.818	.352	158.0	16.33
:35	137	46	"	18.4	2200	1.08	.818	.357	160.1	16.60
AVER.	130.7	72	175	17.9	2188				158.2	16.39

TOTAL STEAM CONSUMPTION = 2221 LB'S

STEAM PER WATER H.P. HOUR = 67.8 LB'S

TOTAL LIFT = 409.1 FT

TEST No 15.

TIME	PRESSURES			VACUUM	R.P.M.	h	COEF.	$Q_1 \frac{cu.ft.}{sec.}$	$Q_2 \frac{gall}{min}$	H. P.
	STEAM I	STEAM II	WATER							
1:00	130	122	200	19.4	2160	.87	.814	.319	143.5	16.95
:10	128	118	"	18.5	2180	.88	.815	.322	145.0	17.15
:20	128	115	"	18.8	2180	.88	.815	.322	145.0	17.15
:30	140	120	"	19.0	2200	.95	.817	.335	150.5	17.80
:40	135	117	"	18.9	2200	.94	.817	.334	150.0	17.75
:50	133	118	"	19.0	2200	.92	.816	.330	148.0	17.50
2:00	143	120	"	19.0	2200	.93	.816	.332	149.0	17.65
:10	140	118	"	19.0	2200	.94	.817	.334	150.0	17.75
:20	146	120	"	18.9	2200	.95	.817	.335	150.5	17.80
:30	136	120	"	18.0	2200	.93	.816	.332	149.0	17.65
:40	140	120	"	18.6	2200	.94	.817	.334	150.0	17.75
:50	130	116	"	18.8	2180	.92	.816	.316	142.0	16.80
3:00	133	118	"	18.8	2180	.89	.815	.323	145.0	17.15
AVER	135.5	118.6	200	18.7	2192				147.5	17.45

TOTAL STEAM CONSUMPTION = 2230 LB'S

STEAM PER WATER H. P. HOUR = 63.9 LB'S

TOTAL LIFT = 466.8 FT.

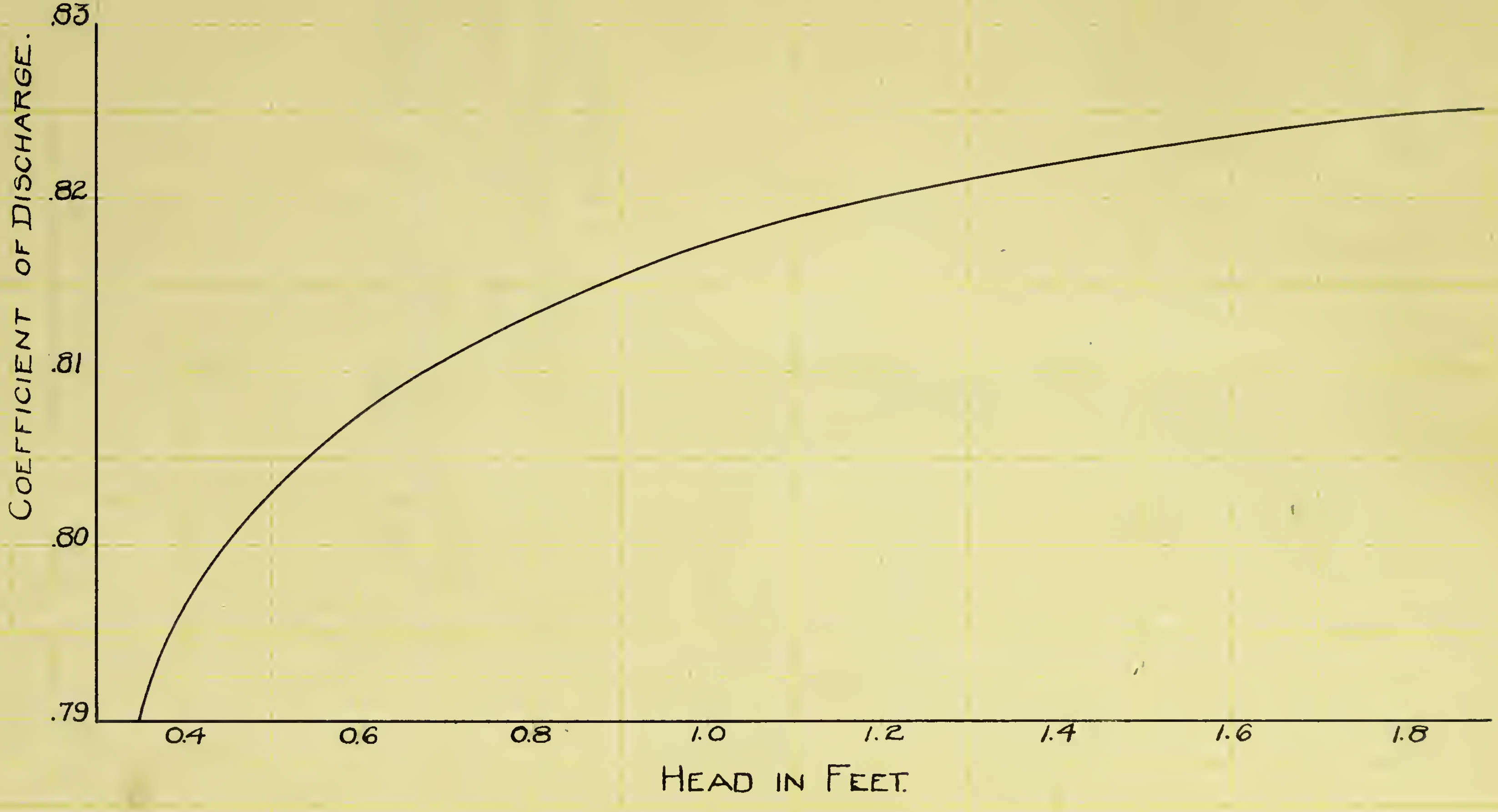
TEST No. 16.

TIME	PRESSURES			VACUUM	R. P. M.	h	COEF.	$Q_1 \frac{cu.ft.}{sec.}$	$Q_2 \frac{gall}{min}$	H. P.
	STEAM I	STEAM II	WATER							
3:05	128	116	217	18.8	2180	.74	.812	.294	131.7	16.87
:15	126	115	"	18.8	2160	.75	.813	.296	132.8	17.03
:25	130	117	"	18.8	2180	.74	.812	.294	131.7	16.87
:35	127	115	"	18.9	2140	.75	.813	.296	132.8	17.03
:45	120	112	"	18.8	2180	.73	.812	.291	131.0	16.78
:55	122	110	"	18.7	2180	.75	.813	.296	132.8	17.03
4:05	122	110	"	18.6	2180	.75	.813	.296	132.8	17.03
:15	120	108	"	18.6	2180	.75	.813	.296	132.8	17.03
:25	122	110	"	18.2	2180	.75	.813	.296	132.8	17.03
:35	132	109	"	18.5	2180	.75	.813	.296	132.8	17.03
:45	121	109	"	18.6	2180	.75	.813	.296	132.8	17.03
:55	131	112	"	18.7	2200	.75	.813	.296	132.8	17.03
5:05	122	108	"	18.7	2180	.77	.813	.299	134.5	17.24
AVER.	125	111.6	217	18.7	2176				132.6	17.00

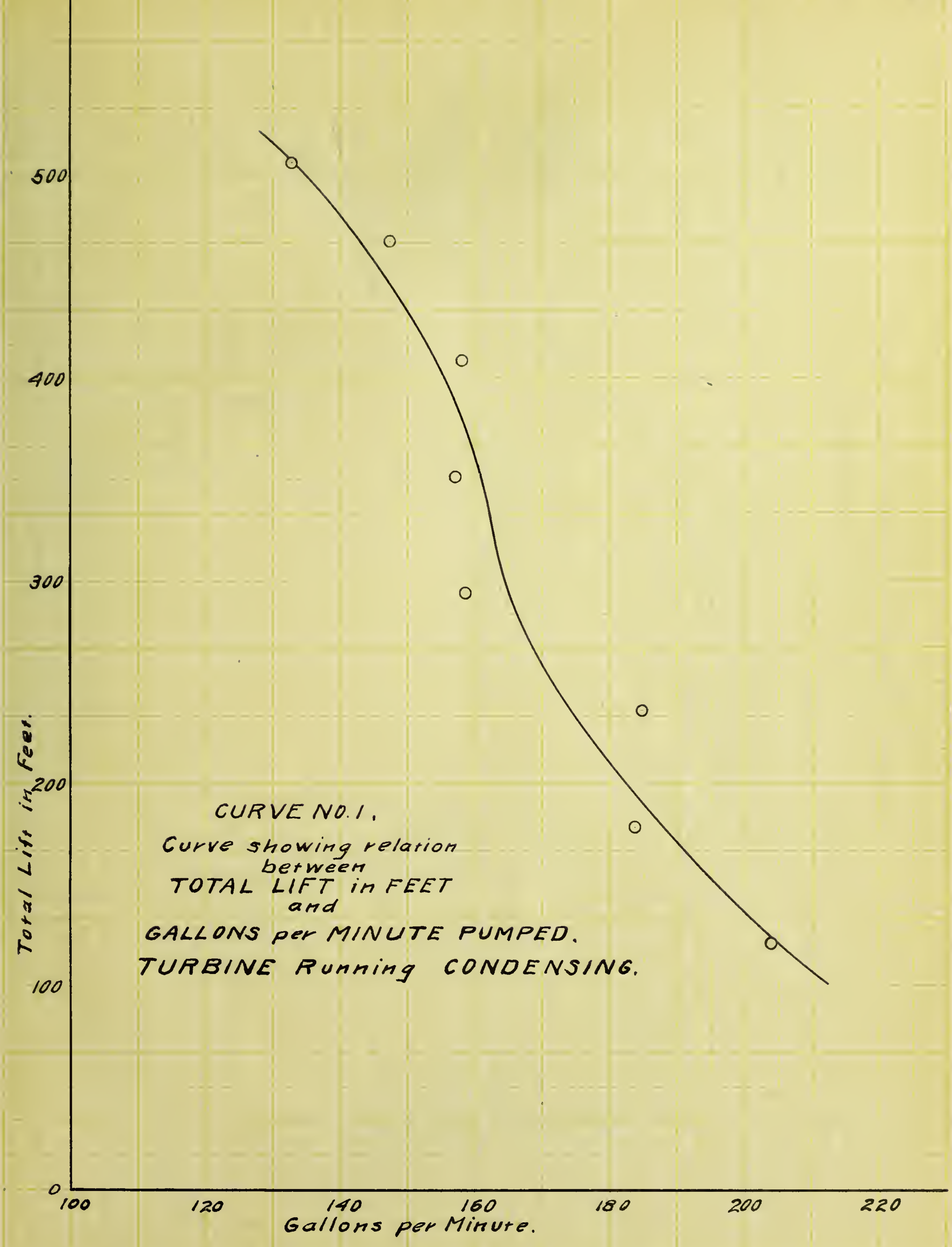
TOTAL STEAM CONSUMPTION = 2206 LB'S

STEAM PER WATER H.P. HOUR. = 64.9 LB'S

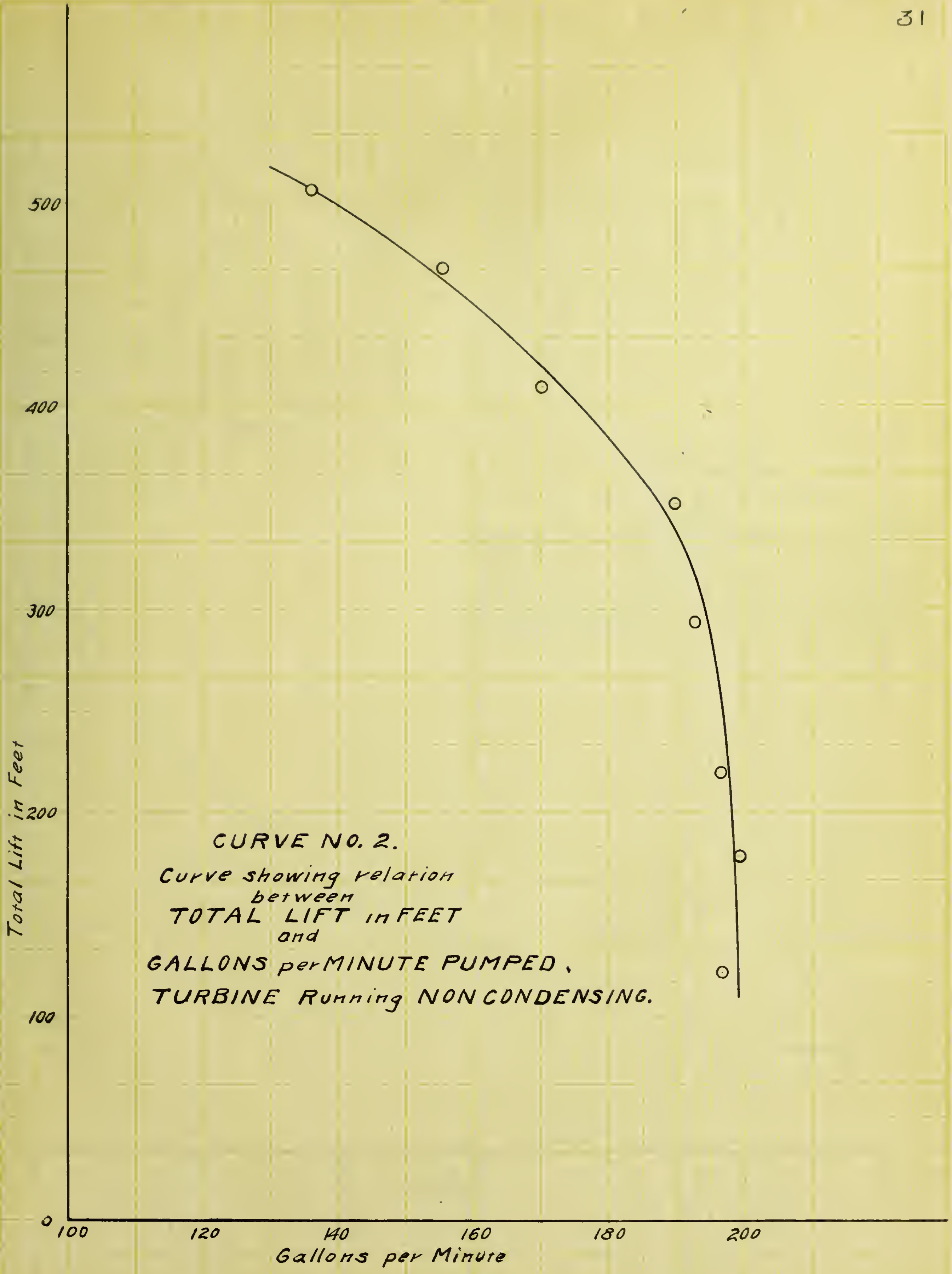
TOTAL LIFT = 506 FT.



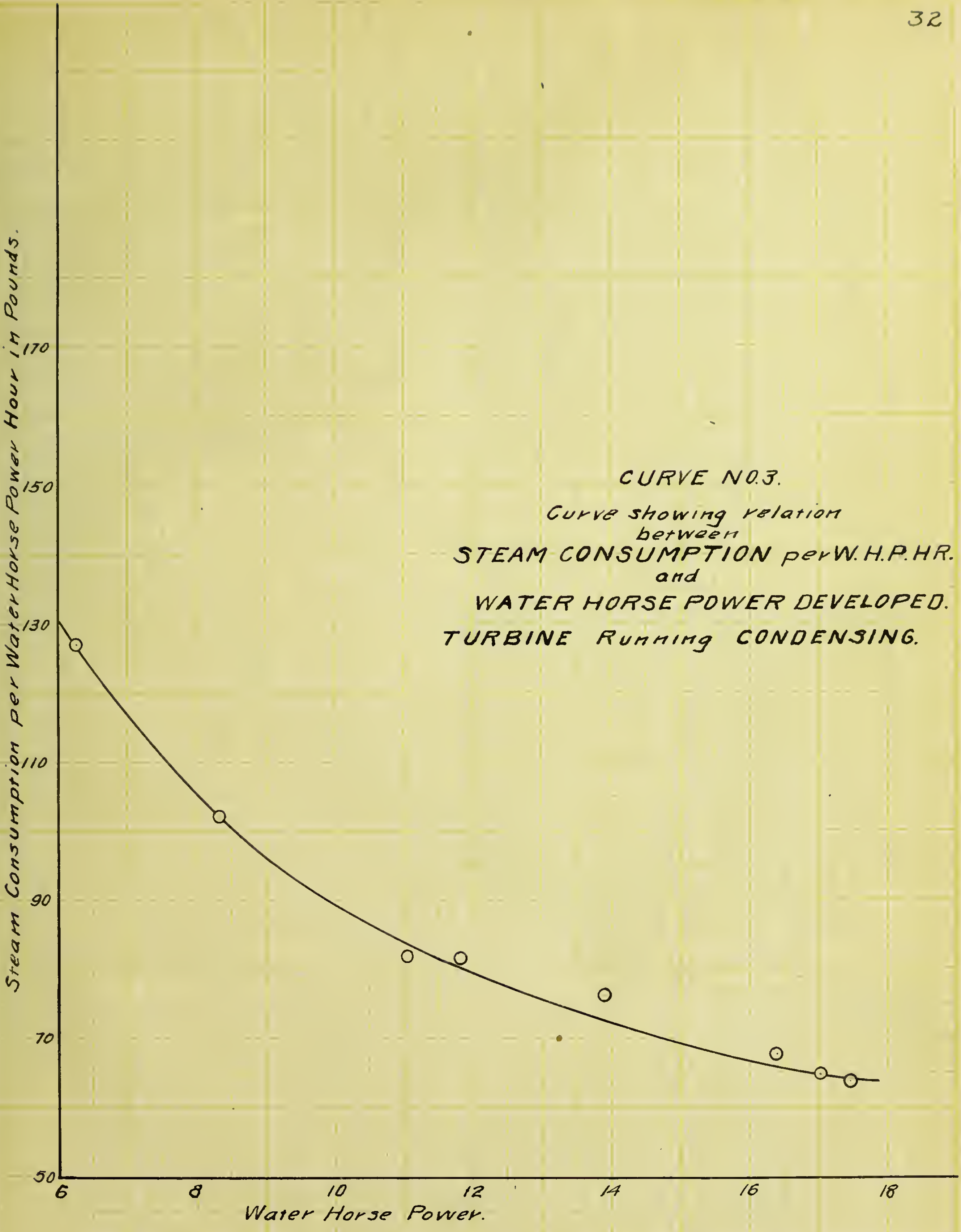
CURVE SHOWING RELATION BETWEEN
HEAD IN FEET AND COEFFICIENT OF DISCHARGE.



CURVE NO. 1.
Curve showing relation
between
TOTAL LIFT in FEET
and
GALLONS per MINUTE PUMPED.
TURBINE Running CONDENSING.



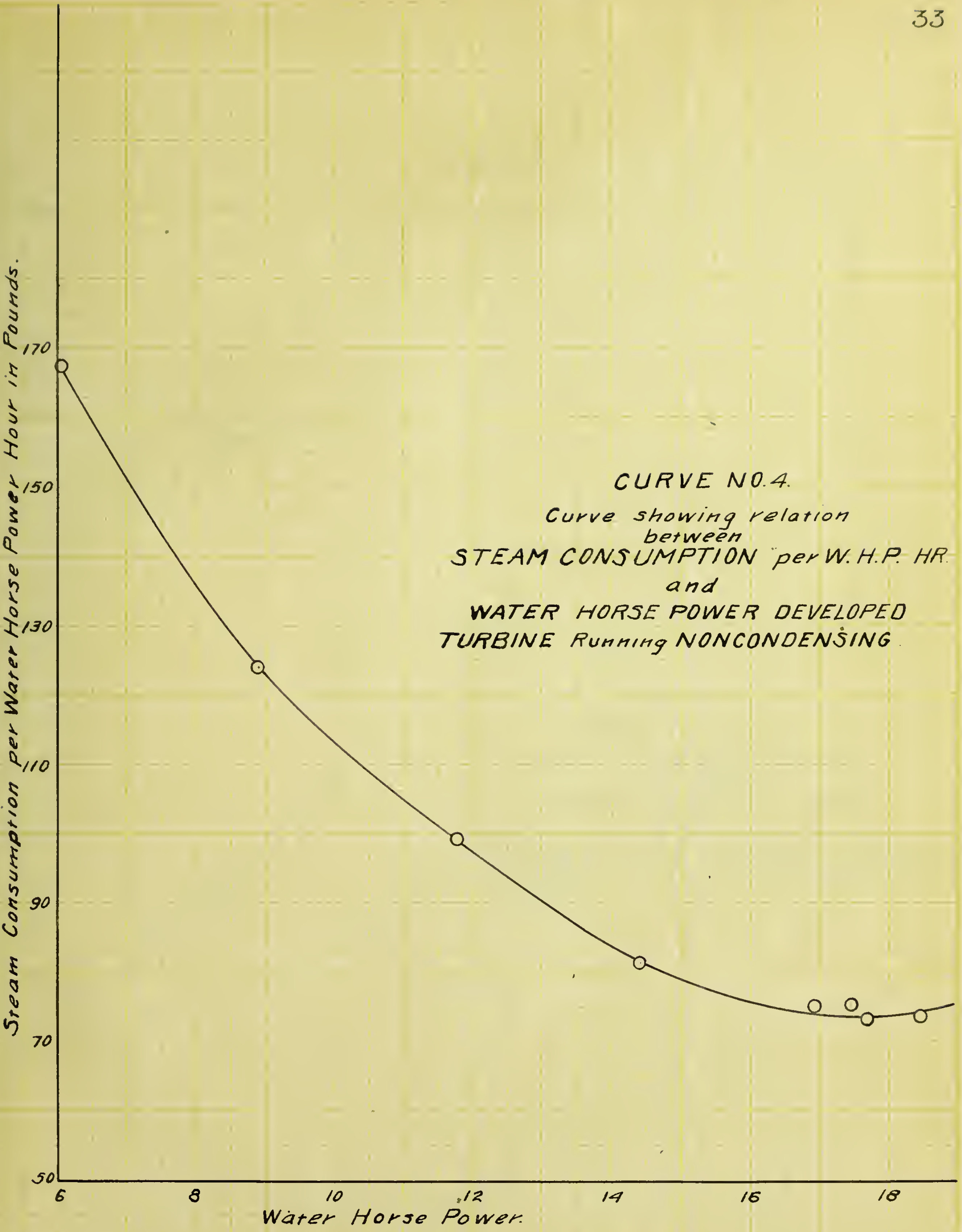
CURVE NO. 2.
Curve showing relation
between
TOTAL LIFT in FEET
and
GALLONS per MINUTE PUMPED.
TURBINE Running NON CONDENSING.



CURVE NO.3.

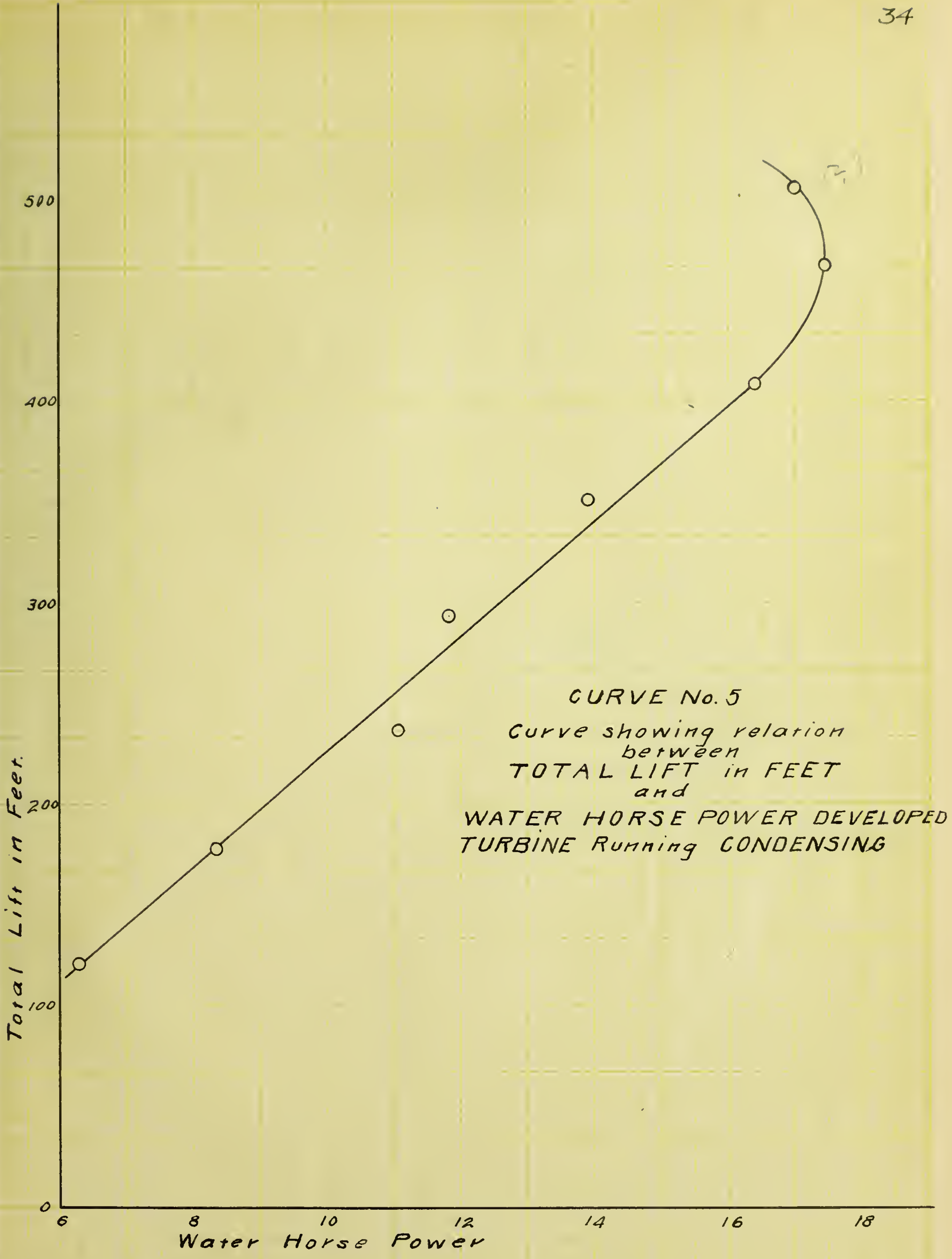
Curve showing relation between STEAM CONSUMPTION per W.H.P.HR. and WATER HORSE POWER DEVELOPED.

TURBINE Running CONDENSING.

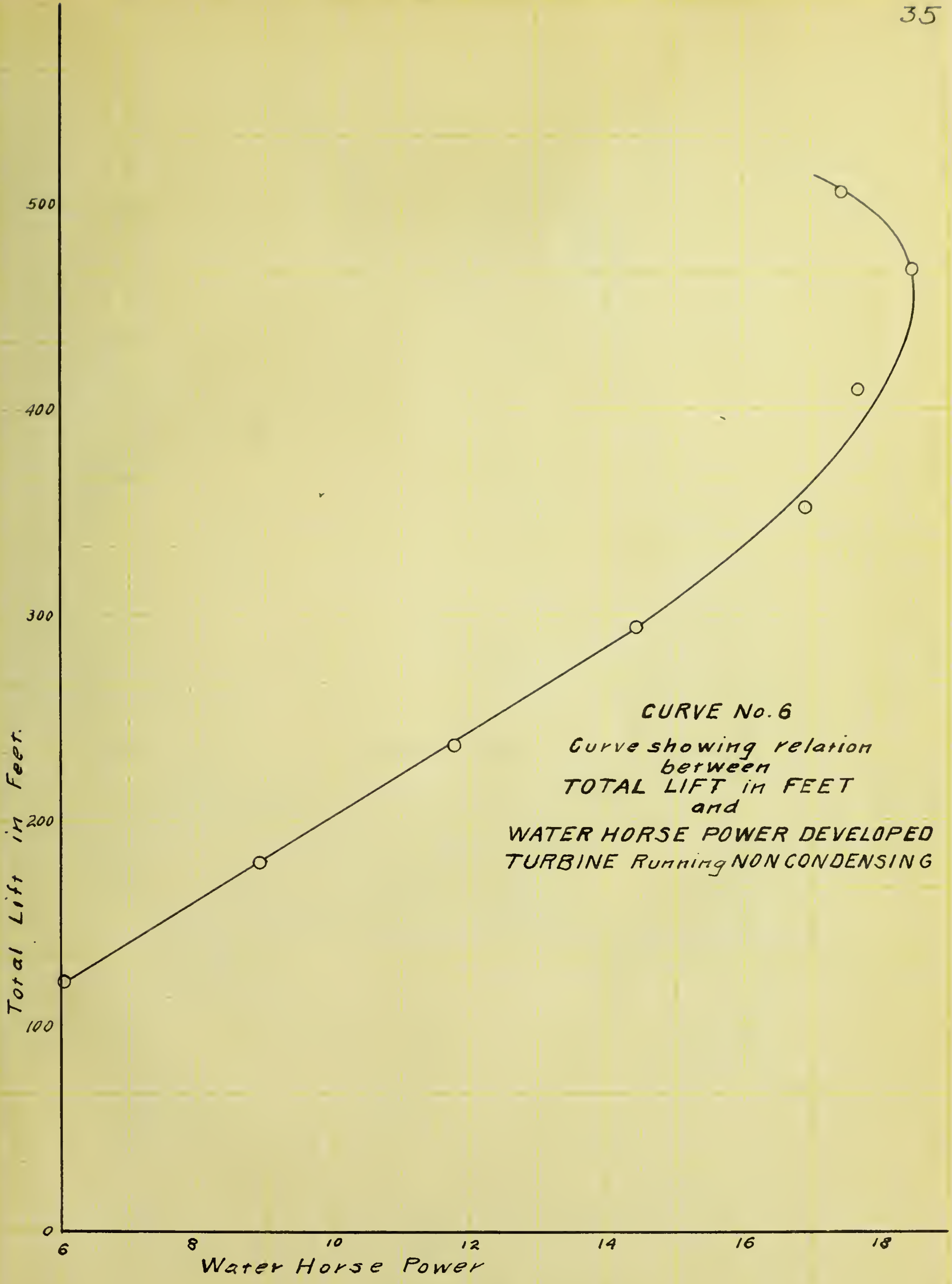


CURVE NO. 4.

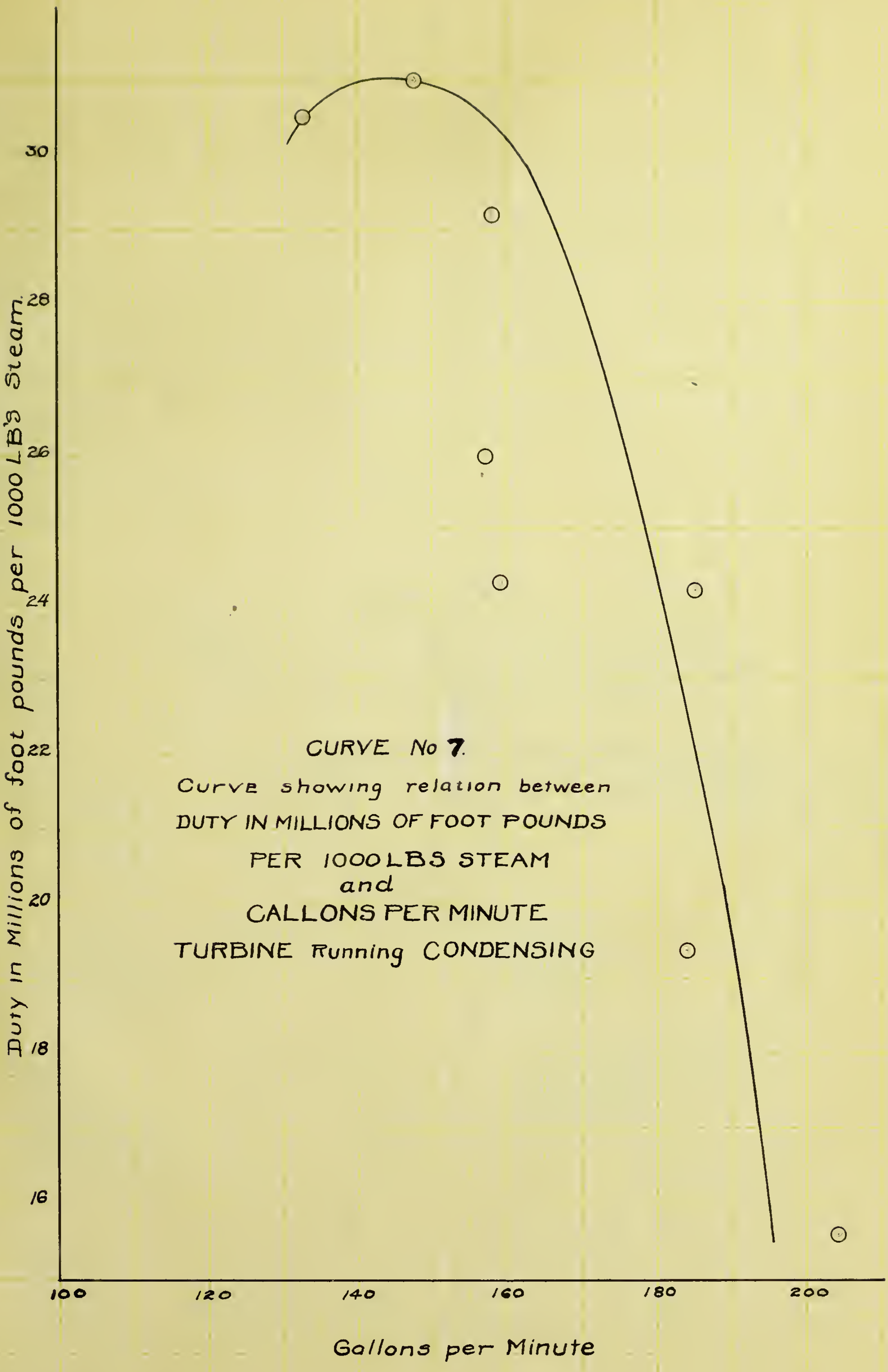
Curve showing relation between STEAM CONSUMPTION per W. H. P. HR. and WATER HORSE POWER DEVELOPED TURBINE Running NONCONDENSING.



CURVE No. 5
Curve showing relation
between
TOTAL LIFT in FEET
and
WATER HORSE POWER DEVELOPED
TURBINE Running CONDENSING

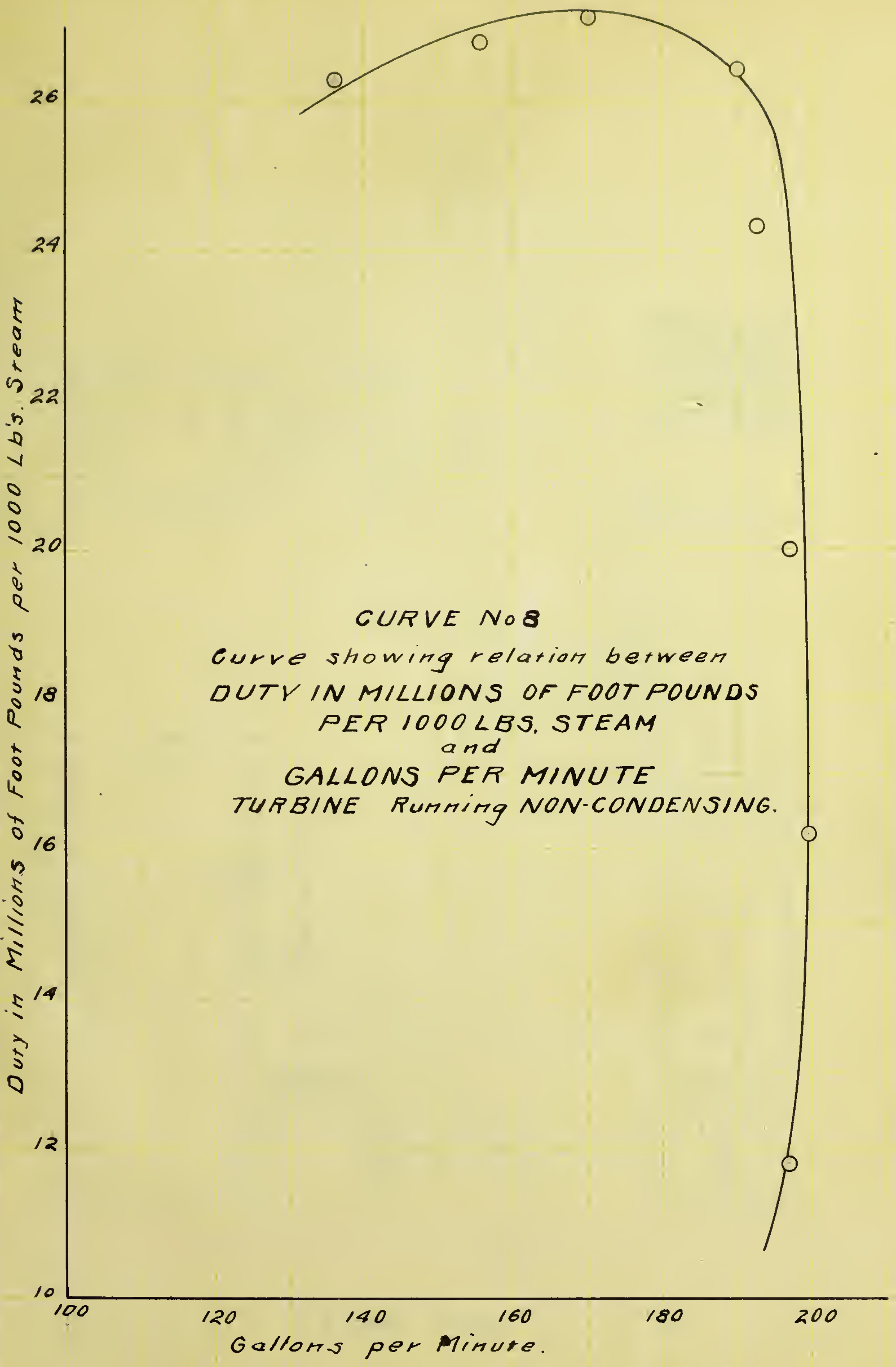


CURVE No. 6
Curve showing relation between
TOTAL LIFT in FEET
and
WATER HORSE POWER DEVELOPED
TURBINE Running NON CONDENSING



CURVE No 7.

Curve showing relation between
DUTY IN MILLIONS OF FOOT POUNDS
PER 1000 LBS STEAM
and
GALLONS PER MINUTE
TURBINE Running CONDENSING



CURVE No 8

Curve showing relation between
DUTY IN MILLIONS OF FOOT POUNDS
PER 1000 LBS. STEAM
and
GALLONS PER MINUTE
TURBINE Running NON-CONDENSING.

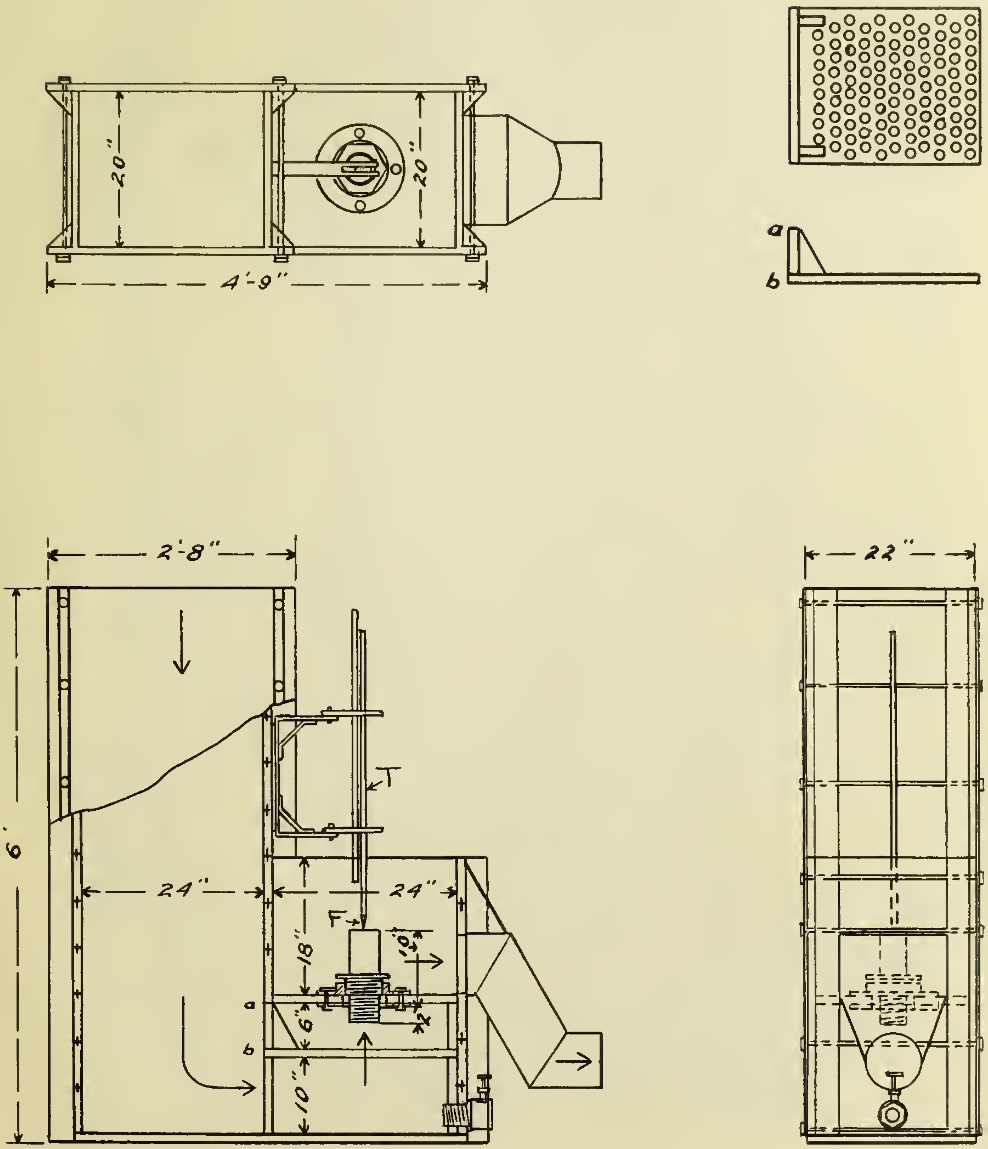

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FIGURE No I

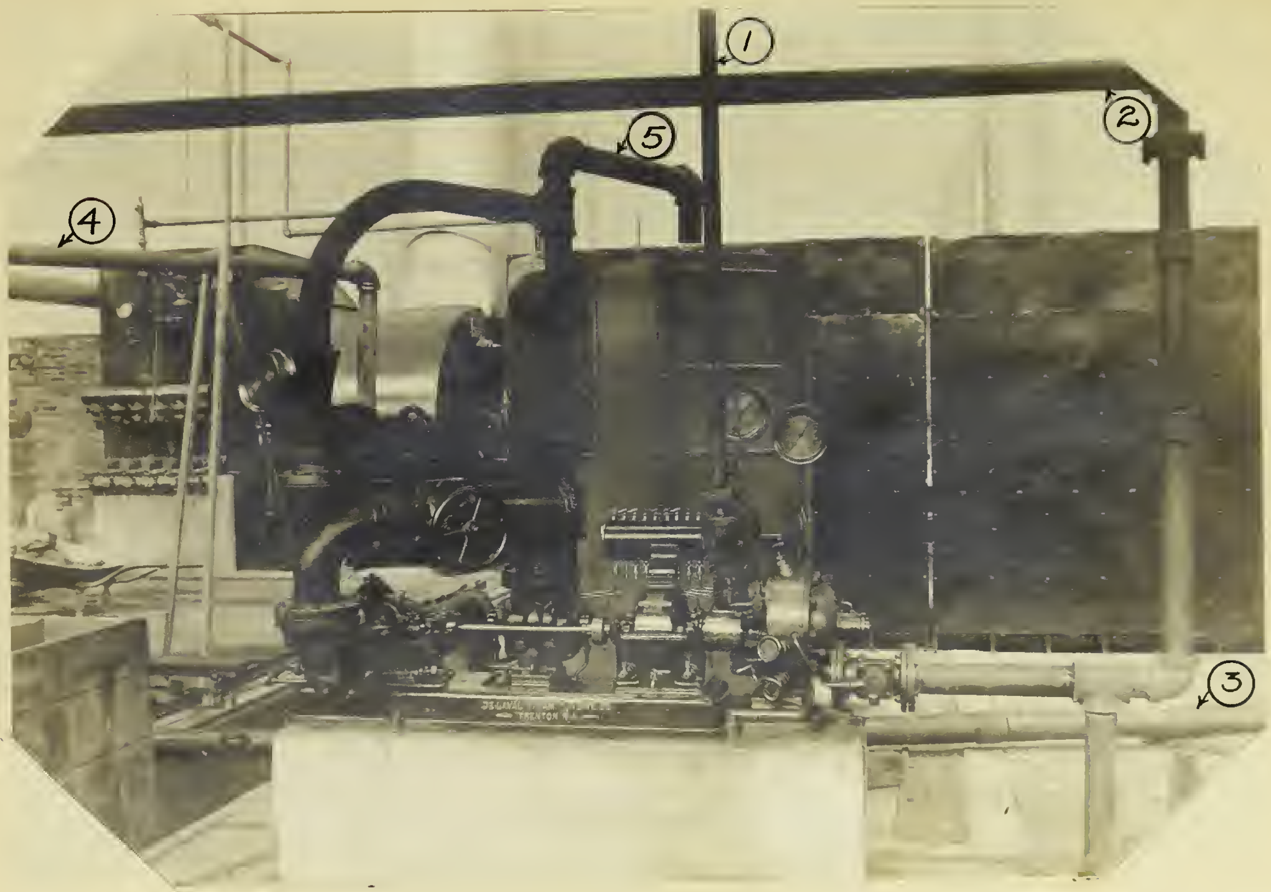

FIGURE No 2

1 - STEAM PIPE FROM MAIN.
2 - EXHAUST PIPE TO CONDENSER
3 - INTAKE COOLING WATER PIPE
4 - EXHAUST COOLING WATER PIPE
5 - DELIVERY PIPE FROM PUMP.

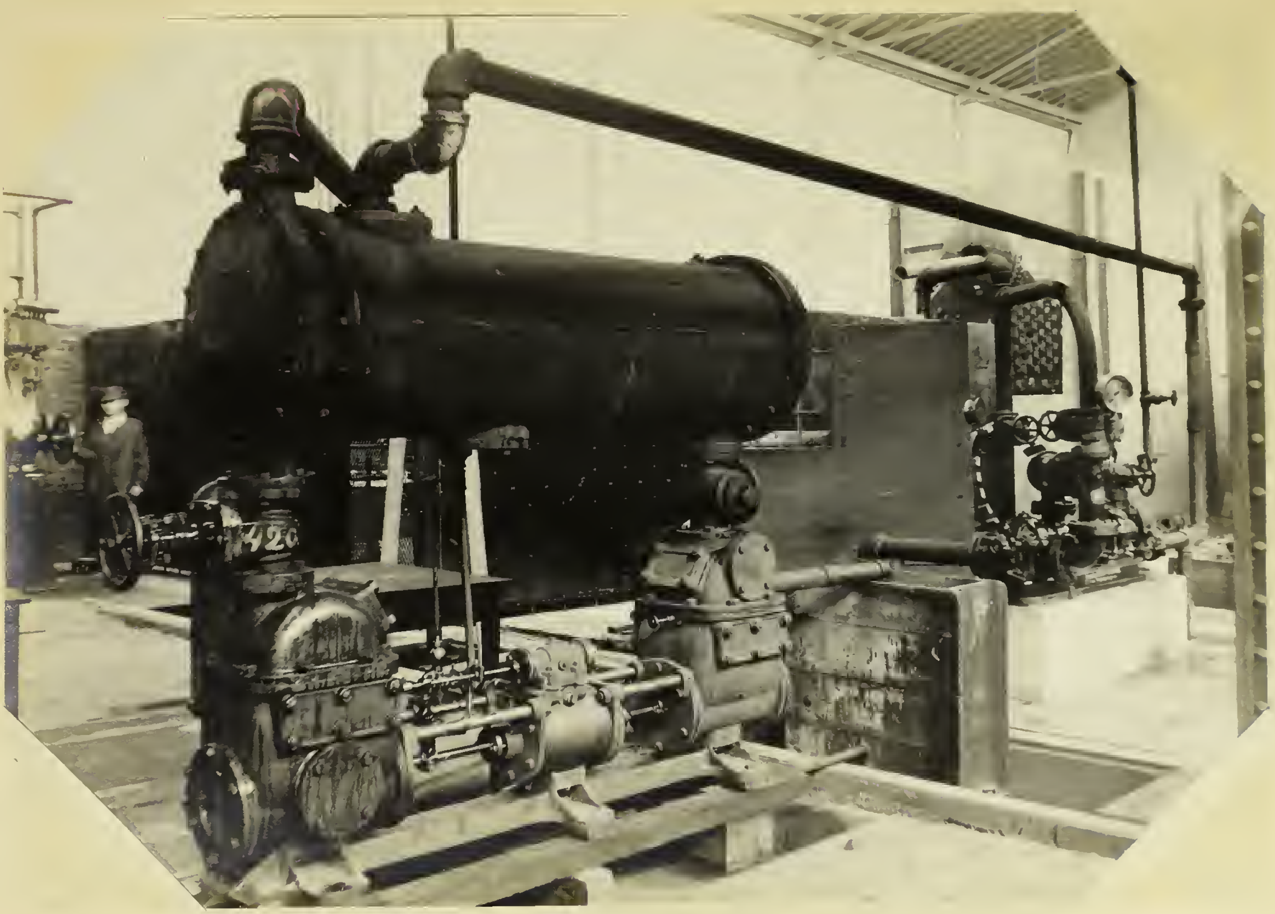

FIGURE No 3.

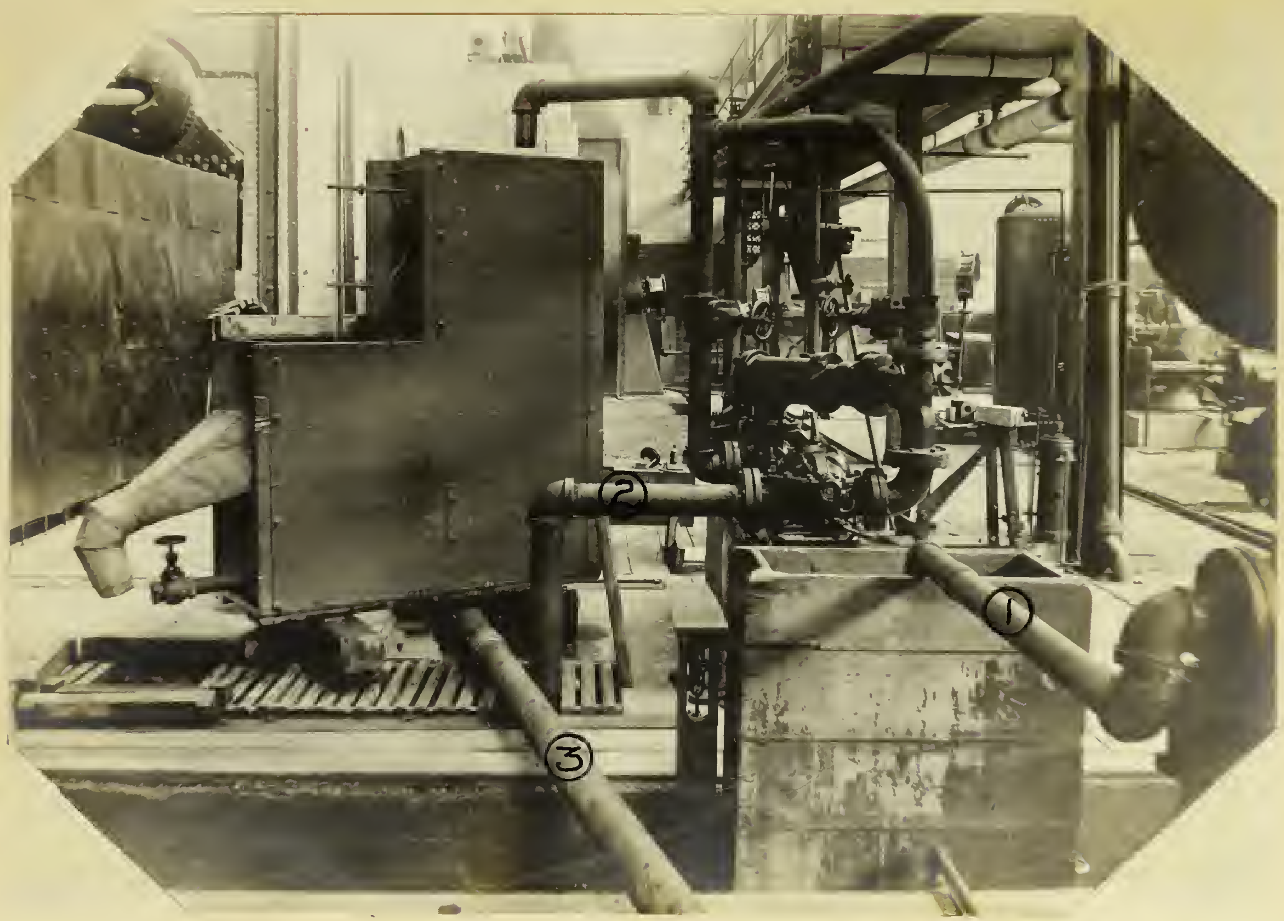

FIGURE No 4

1-CONDENSED STEAM EXHAUST.
2-INTAKE PIPE TO PUMP.
3-INTAKE COOLING WATER PIPE

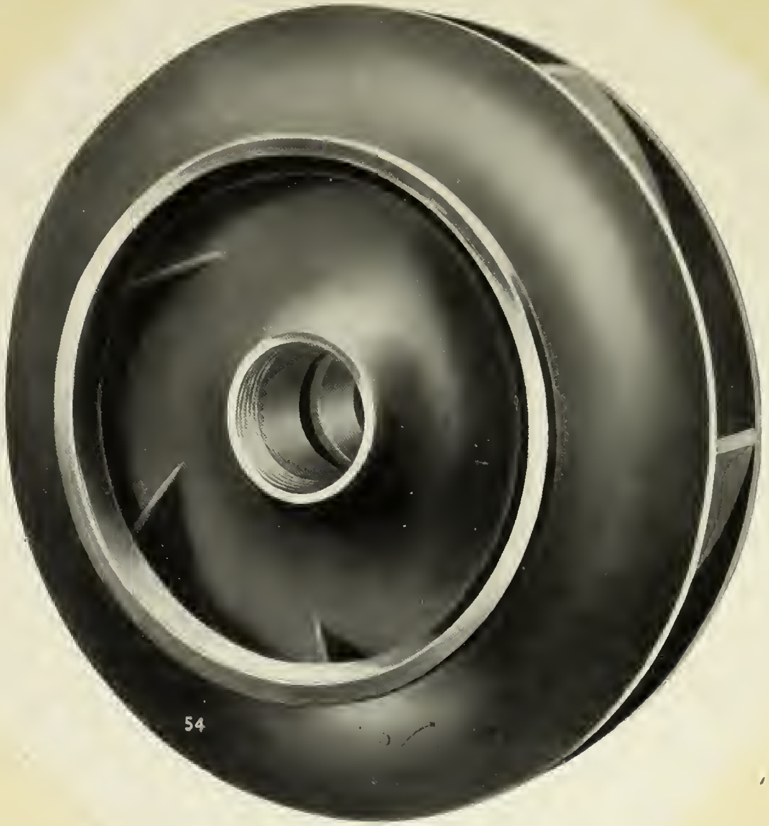

Fig. 3.—Impeller.

FIGURE No5.

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